

This Page Is Inserted by IFW Operations  
and is not a part of the Official Record

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning documents *will not* correct images,  
please do not report the images to the  
Image Problem Mailbox.**



(12) UK Patent (19) GB (11) 2 172 325 (13) B

(54) Title of Invention

Drilling apparatus

(51) INT CL<sup>4</sup>; E21B 7/06

(21) Application No  
8506519

(22) Date of filing  
17 Mar 1986

(30) Priority data

(31) 8506866  
8517749

(32) 16 Mar 1985  
13 Jul 1985

(33) United Kingdom (GB)

(43) Application published  
17 Sep 1986

(45) Patent published  
20 Jul 1988

(73) Proprietor(s)  
Cambridge Radiation  
Technology Limited

(Incorporated in United  
Kingdom)

Cambridge Science Park  
Milton Road  
Cambridge CB4 4BH

(72) Inventor(s)  
Gordon Douglas  
Peter Allen

(74) Agent and/or  
Address for Service  
Keith W Nash & Co  
Pearl Assurance House  
90-92 Regent Street  
Cambridge CB2 1DP

(52) Domestic classification  
(Edition J)  
E1F CU

(56) Documents cited  
GB A 2077811  
GB A 2017191  
GB 1241063

(58) Field of search  
E1F  
Selected US  
specifications from  
IPC sub-class E21B

10 6/86/10/1

## Drilling Apparatus

### Field of the Invention

This invention relates to drilling apparatus, and in particular to apparatus for deflecting a rotatable drilling tube to control the drilling course of direction.

### Summary of the Invention

According to the invention there is provided apparatus for deflecting a rotatable drilling tube to control the drilling course, comprising actuating means which do not rotate with the drilling tube and which are disposed between two support means which support the drilling tube in a radial sense at two positions spaced along the length of the drilling tube, the actuating means applying to the drilling tube a deflecting force having a magnitude and direction which are controllable during rotation of the drilling tube to impart a required curvature to the drilling tube between the two support means in order to control the drilling course.

In one embodiment the support means are stabilisers which engage the bore hole wall which provides a reaction force against the deflecting force applied by the actuating means.

In an alternative embodiment the support means are bearings which rotatably support the drilling tube within a casing disposed within the bore hole, the casing providing a

reaction force against the deflecting force applied by the actuating means.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

5        Figure 1 is a diagrammatic view of the bottom hole assembly of drilling apparatus forming an embodiment of the invention,

Figure 2 is a detailed view, on an enlarged scale, of part of Figure 1,

10        Figure 3 is a sectional view on the line III-III of Figure 2,

Figure 4 is a diagrammatic view of the bottom hole assembly of a second embodiment of the invention,

Figure 5 is a detailed view of part of Figure <sup>4</sup>~~2~~,

15        Figure 6 is a sectional view on the line VI-VI of Figure 5,

Figure 7 is a detailed view of another part of Figure 3, and

20        Figures 8, 9 and 10 are respectively side, end and plan views of a flexible enclosure of the drilling apparatus.

#### Detailed Description of the Drawings

Referring to Figure 1, the drilling apparatus comprises a

rotatable drilling tube 10 carrying at its extremity a drill bit 12. The drilling tube 10 is supported and centred in a bore hole 14 by two spaced stabilisers, namely a near bit stabiliser 16 and a far bit stabiliser 18. Between the stabilisers 16 and 18 is located a control stabiliser 20 which applies to the drilling tube 10 a controlled lateral force and displacement (indicated by arrow 22) in order to deflect the tube 10 between the spaced supports constituted by the stabilisers 16 and 18. Figure 1 illustrates the undeflected drilling tube at 24 and the deflected drilling tube at 26, the change in drilling direction being indicated by the angle 28.

Figure 2 shows a half section through the control stabiliser 20, on an enlarged scale. Referring to Figure 2, the control stabiliser 20 has a housing 31 which contains sensing means, information storage means and comparison means, together with batteries, hydraulic pump, valves and other equipment necessary for the operation of the actuating means. The batteries are for powering the electronic and other equipment associated with the control means. The hydraulic pump is driven from the rotating drilling tube by virtue of the relative rotation between the rotating drilling tube and the normally stationary housing. The sensing device senses the actual drilling direction and this is compared in the comparison means with the desired drilling direction stored in the information storage means, any difference being used to apply a deflecting force to the drilling tube 10 so that the drilling course follows the desired drilling course.

The wall contact assembly 33, which is externally similar to a conventional stabiliser, provides the reaction to the radial force applied to the drilling tube by means of the

actuator assembly 34. The wall contact assembly may rotate with the drilling tube, in which case the forward joint 35, which is connected to the wall contact assembly by a nose casing 36, is arranged to allow angulation about axes normal to and passing through the axis of the drilling tube, while preventing rotation about the axis of the drilling tube and minimising radial and axial movement. Bearings 37 connect the rotating wall contact assembly with the non-rotating assembly consisting of an angulation coupling 38, an actuator casing 39 and an anti-rotation device 40. The angulation coupling 38 is similar in performance to the forward joint and allows angulation about axes normal to and passing through the axis of the drilling tube but prevents relative rotation about the axis of the drilling tube and prevents all relative translational movements. The anti-rotation device 40 is designed to apply radial force to the bore hole wall 14 and provide torsional resistance preventing rotation, while having minimal resistance to axial movement.

The housing 31 is connected rigidly to an actuator bridge member 41. This assembly is located onto the drilling tube by means of spaced bearings 42. This assembly is also connected to the actuator casing by means of a rear joint 43 which has the same properties as the forward joint and similar properties to the angulation coupling.

The actuator assembly 34 consists of four individual actuators 44. These actuators 44 lie within the annular space 46 between the actuator casing 39 and the actuator bridge member 41 and each actuator is disposed at equal intervals around the periphery, as best shown in Figure 3. The movement of the drilling tube relative to the wall contact assembly is achieved by applying different

pressures, in a controlled manner, to each of the four actuators 44.

5 The form of the actuators could be a flexible enclosure such as a hose or tube 44 or a variation thereof, with one end blanked off and the other end connected to a hydraulic supply and return pipe. The flexible material could be woven polyester or nylon coated with a suitable elastomer such as Viton.

10 Four of these tubes 44 are fitted into the annular space 46 reserved for the actuators, as shown in Figure 3. In the neutral position the cross section of each tube 44 would be partially flattened. As hydraulic fluid is supplied to any one actuator it has the tendency to return to its circular cross section and hence a radial force is applied at the actuator location which is dependent on the  
15 hydraulic fluid pressure and the cross sectional geometry of the actuator. Provided the actuator diametrically opposite to the actuator being filled is allowed to vent, the actuator bridge member 41 and hence the drilling tube  
20 10 will be moved radially with respect to the actuator housing. The use of four actuators allows the actuator bridge member 41 to be positioned at any location relative to the actuator housing only within the limits of maximum radial movement.

25 An alternative mode of operation is with the wall contact assembly not rotating with the drilling tube. In this case the forward joint 35 is located on the drilling tube by means of a bearing assembly 45 and the bearings 37 are locked to provide a rigid connection. It may be useful to  
30 configure this form of invention so that the modes of operation can be interchanged by means of simple

adjustment. With the wall contact assembly not rotating it may be that the anti-rotation device is not required, this function being provided by the wall contact assembly itself.

- 5 It will be appreciated that in the embodiment of Figures 1 to 3 the control stabiliser 20 applies to the rotating drilling tube 10 a deflecting force which has a magnitude and direction to impart a required curvature to the drilling tube 10 between the stabilisers 16, 18, in order  
10 to control the drilling course. The reaction against the deflecting force is provided by the bore hole wall at the locations of the stabilisers 16, 18, as indicated by arrows 21 in Figure 1.

- In the embodiment of Figures 4 to 10, parts equivalent to those of Figures 1 to 3 have been given the same reference  
15 numerals increased by 100. Hence, in Figure 4, the drilling tube 110 extends through a stabiliser 118 and an optional stabiliser 116. An intermediate stabiliser 150 is provided, and instead of the control stabiliser 20, the  
20 embodiment of Figures 4 to 10 has a control module 152.

- The module 152 has a cylindrical casing 154 having end seals 156 and enclosing bearings 158, 160 and actuating means 162 for deflecting the drilling tube 110. Referring  
25 to Figures 5 and 6, the actuating means 162 comprise four flexible enclosures in the form of bags 164 located in the annular space between the casing 154 and a bearing sleeve 166. The bearing sleeve 166 does not rotate with the drilling tube 110 but is mounted on the latter by bearings 161. Fluid is fed to the bags 164 through hydraulic pipes  
30 168 which communicate with a pump (170, Figure 7) through a valve block and reservoirs unit 172.

The pump 170 is located in the annular space between the casing 154 and a bearing sleeve 174 which is non-rotatably mounted on the rotatable drilling tube 110 by a bearing 176. Between the drilling tube 110 and the inner race of the bearing 176 is located an eccentric sleeve 178 which rotates with the drilling tube 110 and causes the bearing sleeve 174 to oscillate in the radial direction of arrow X in Figure 7, thereby to apply a pumping action to a flexible enclosure or bag 178 of the pump. The flexible bag 178 is similar in construction to one of the flexible bags 164. An anti-rotation pin 180 interconnecting the casing 154 and the bearing sleeve 174 prevents rotation of these two components.

Figures 8, 9 and 10 show the construction of a representative bag 164 or the bag 178. The bag 164 or 178 has a fabric body formed into a tubular configuration, opposite edges being sealed by metallic clamping strips 182, from one of which extends a hydraulic supply or return pipe forming the hydraulic pipe 168.

The magnitude and direction of the deflecting force applied by the bags 164 to the drilling tube are controlled by appropriate control of the application of hydraulic pressure from the pump bag 178 to the actuator bags 164. In order to achieve the required deflecting force, two adjacent bags 164 are individually pressurised to the required extent, and the two remaining bags 164 are completely depressurised, this being achieved by appropriate energisation of the valves in the valve block and reservoirs unit 172.

In the embodiment of Figures 4 to 10, the deflecting force

is applied to the drilling tube, in the desired magnitude and direction, to impart a curvature to the tube, as indicated at 124 in Figure 4. This controlled curvature controls the drilling direction. The reaction to the deflecting force is borne within the casing 154, the bearings 160, 158 providing reactive forces on the tube. It will be noted that the bore hole wall provides no reactive forces to the tube 110 through the intermediary of the casing 154.

Instead of flexible bags, hydraulic pistons may be used to apply for the drilling tube a deflecting force having a controlled magnitude and radial direction.

Attention is drawn to the applicants' specifications GB-A-2177738 and GB-A-2172324 which disclose similar apparatus.

Claims

1. Apparatus for deflecting a rotatable drilling tube to control the drilling course, comprising actuating means which do not rotate with the drilling tube and which are disposed between two support means which support the drilling tube in a radial sense at two positions spaced along the length of the drilling tube, the actuating means applying to the drilling tube a deflecting force having a magnitude and direction which are controllable during rotation of the drilling tube to impart a required curvature to the drilling tube between the two support means in order to control the drilling course.
2. Apparatus according to claim 1, wherein the support means are stabilisers which engage the bore hole wall which provides a reaction force against the deflecting force applied by the actuating means.
3. Apparatus according to claim 1, wherein the support means are bearings which rotatably support the drilling tube within a casing disposed within the bore hole, the casing providing a reaction force against the deflecting force applied by the actuating means.
4. Apparatus according to any of the preceding claims, wherein the actuating means are hydraulic pistons for applying the deflecting force with a controlled magnitude and radial direction.
5. Apparatus according to any of claims 1 to 3, wherein the actuating means comprise a plurality of flexible .

enclosures which are capable of being pressurised by fluid to impart the deflecting force to the drilling tube.

6. Apparatus according to claim 5, wherein there are four similar flexible enclosures, symmetrically arranged at equi-angularly spaced positions around the drilling tube.

7. Apparatus according to claims 3 and 6, wherein the flexible enclosures are located in an annular space defined at its radially outer extent by the casing and at its radially inner extent by a bearing sleeve within which the drilling tube is rotatably mounted.

8. Apparatus according to any of the preceding claims, wherein the deflecting force is controlled at the location of the actuating means.

9. Apparatus for deflecting a rotatable drilling tube, constructed and arranged substantially as herein particularly described with reference to the accompanying drawings.

---

1/8

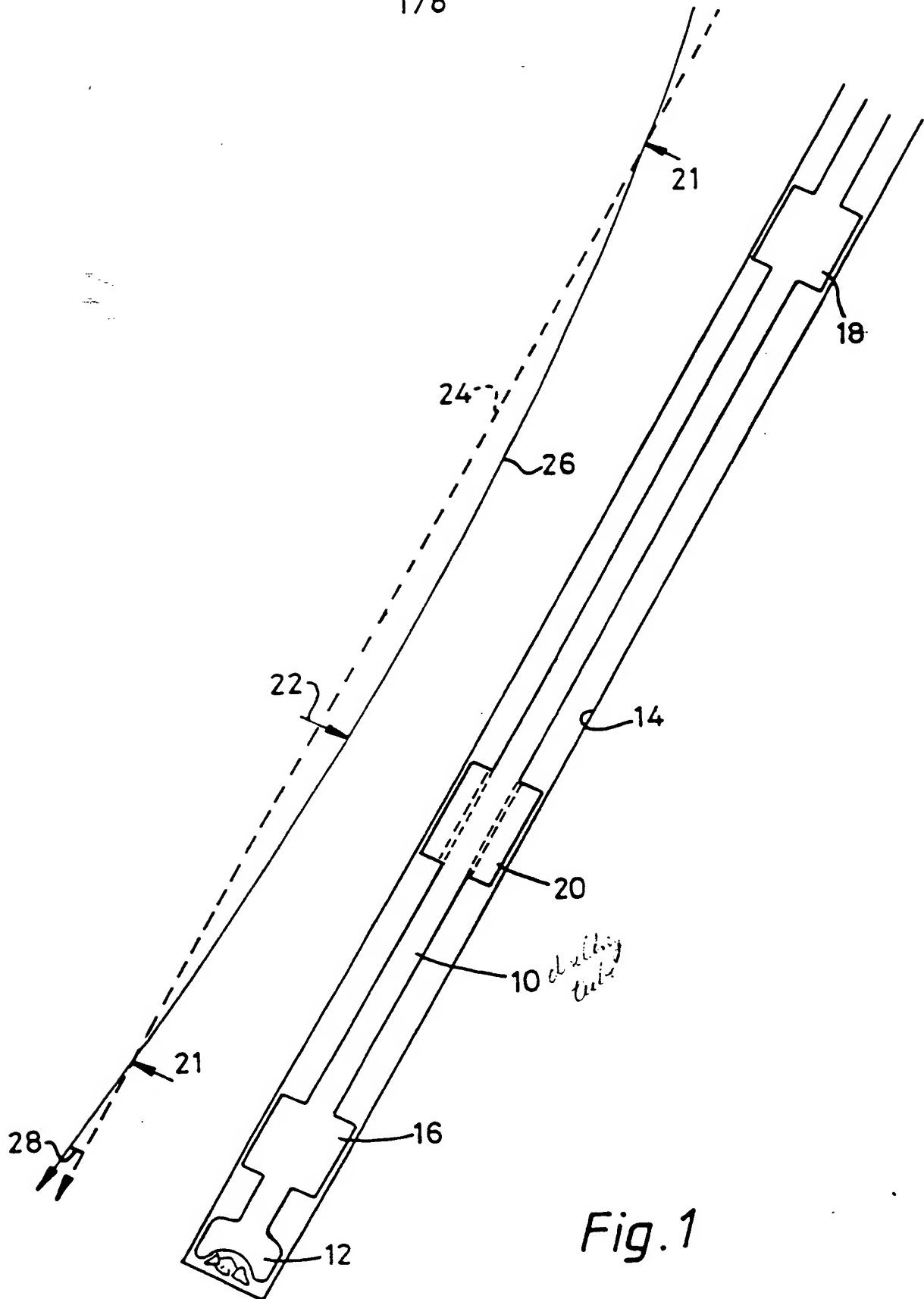


Fig. 1

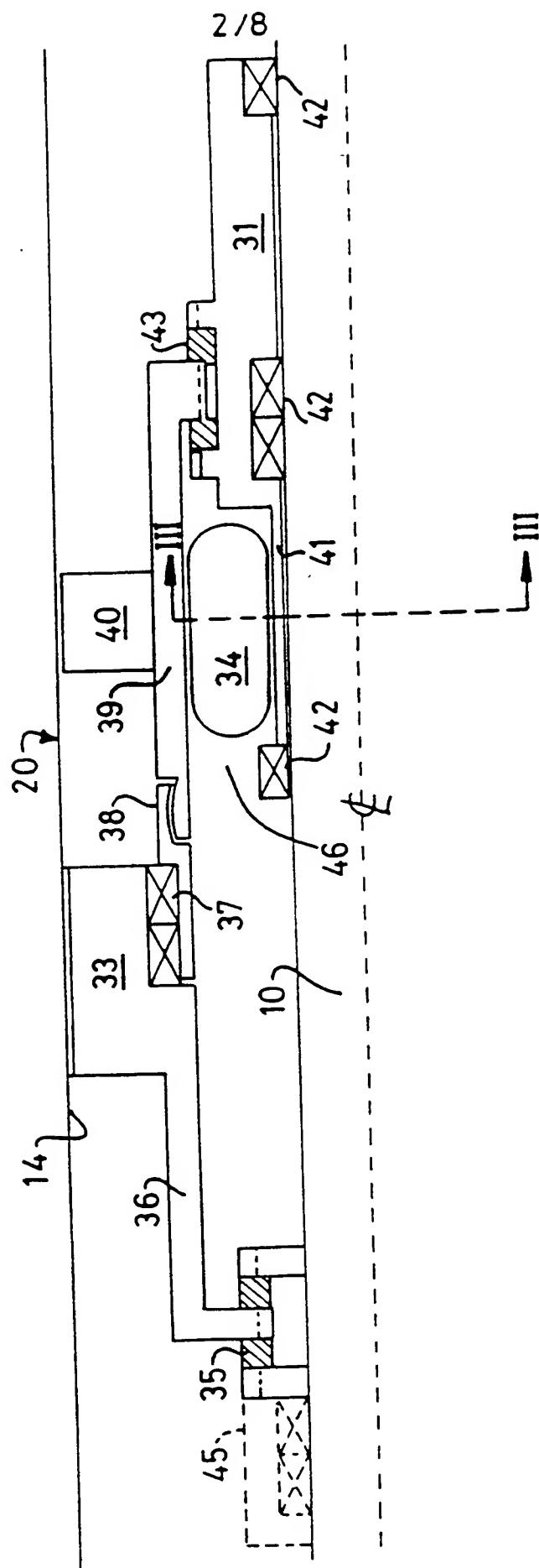
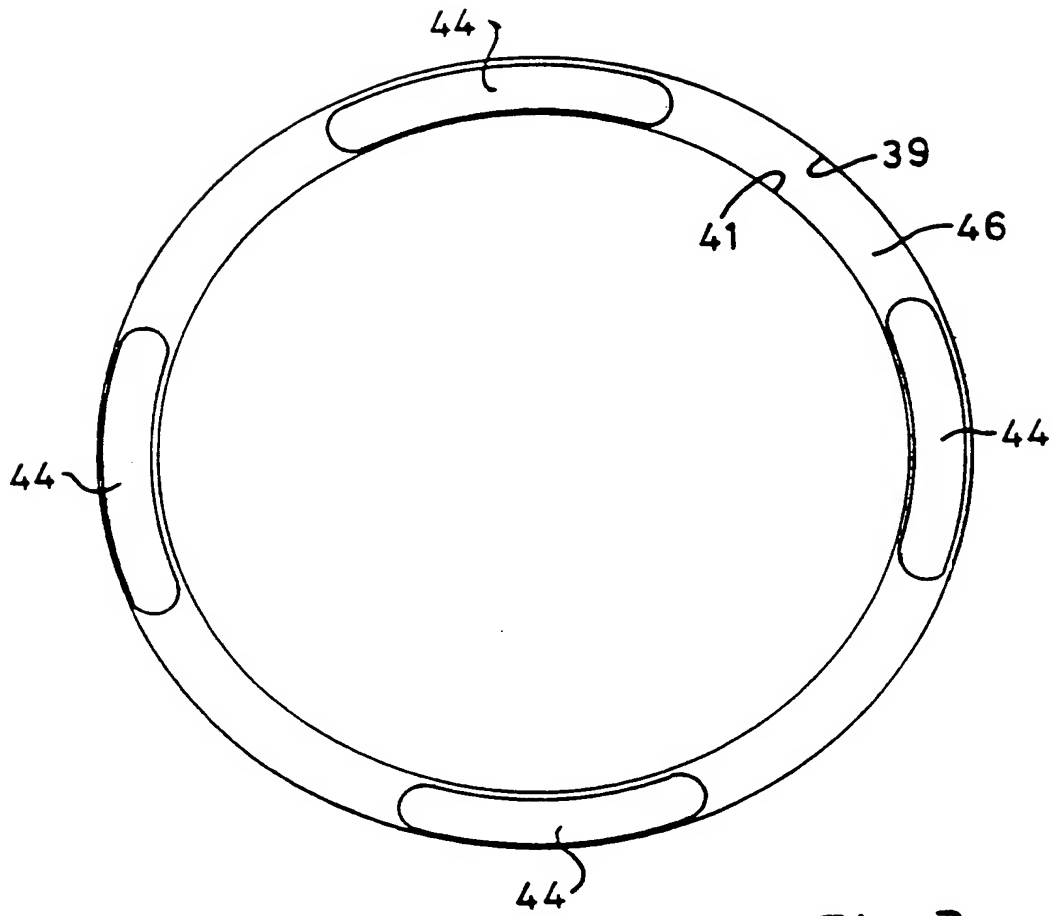
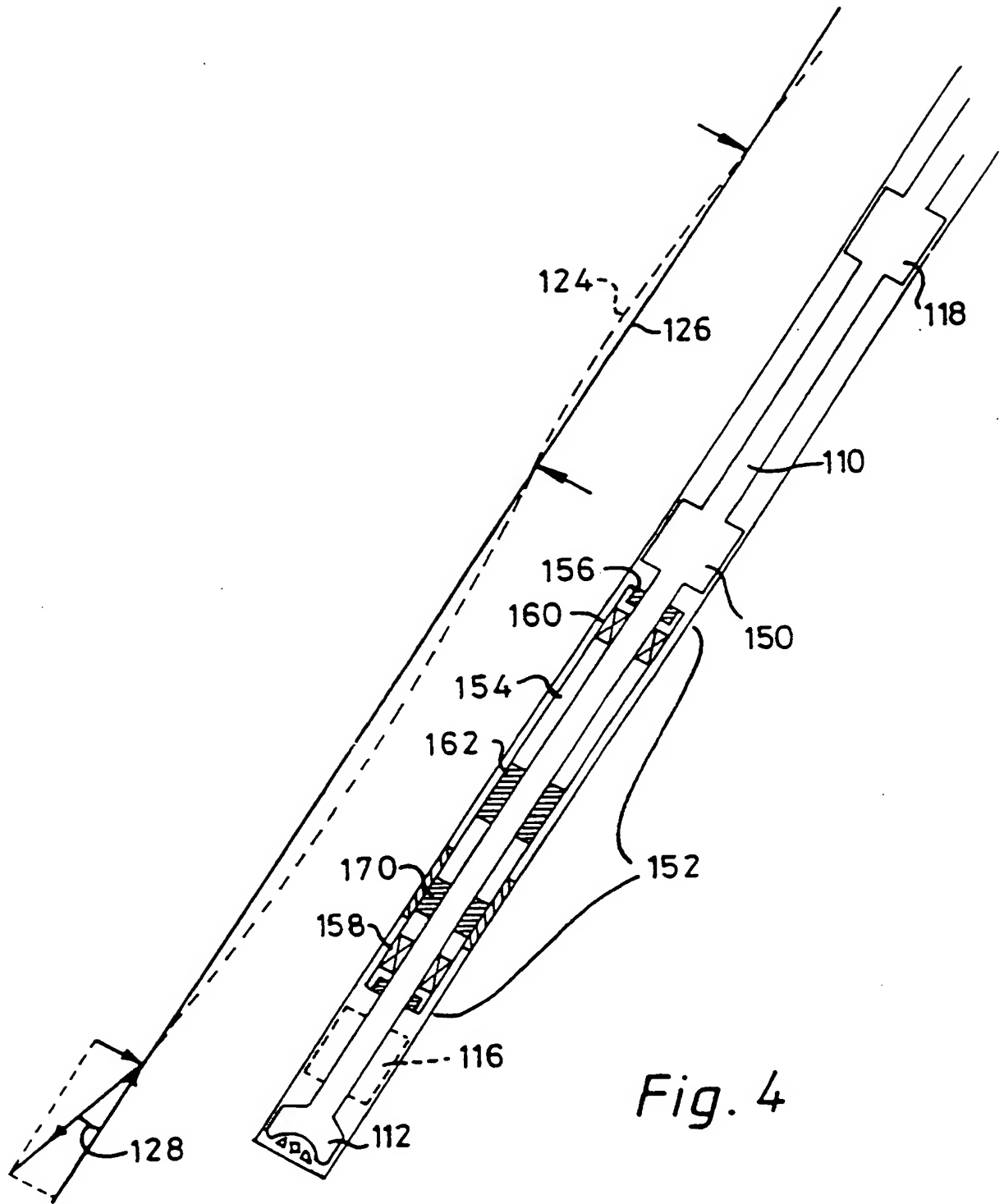


Fig. 2

*Fig. 3*



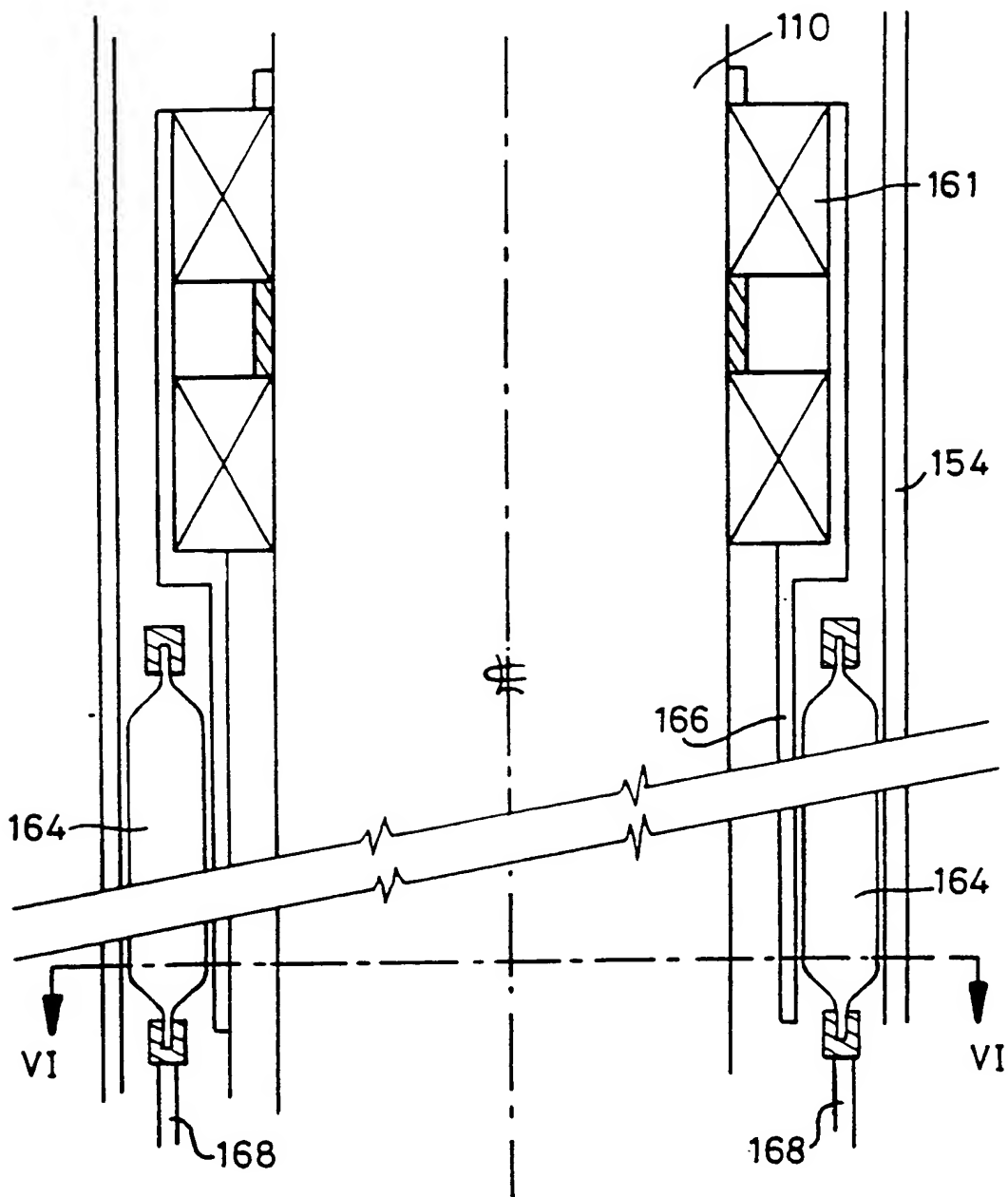
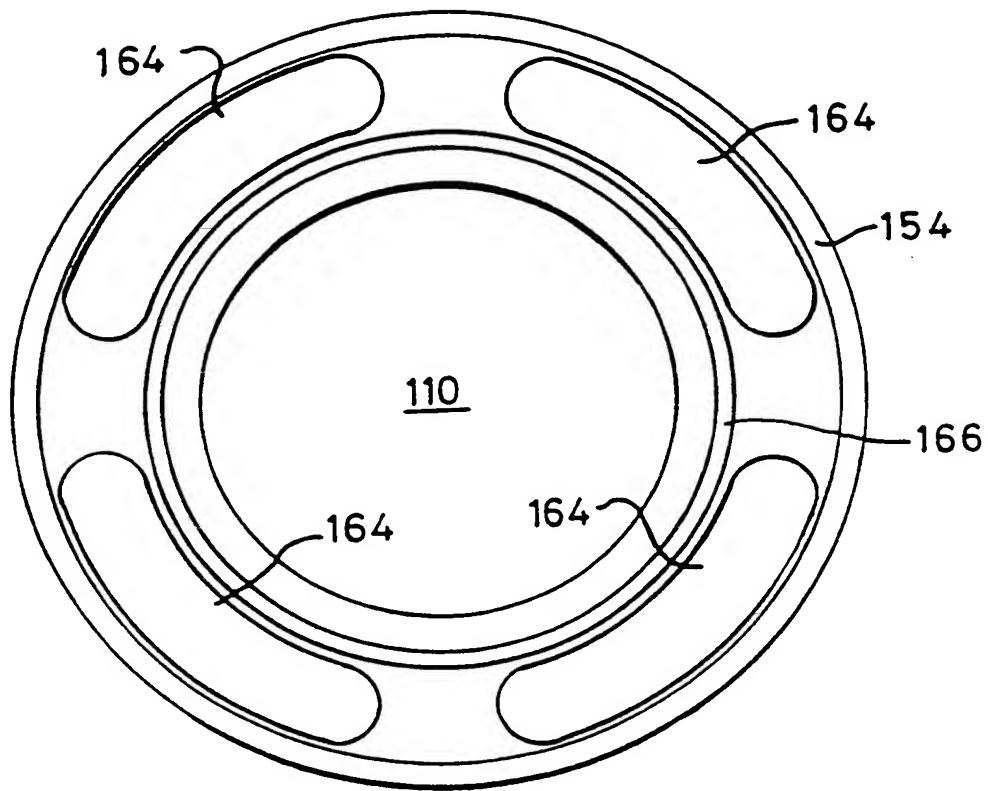


Fig. 5



*Fig. 6*

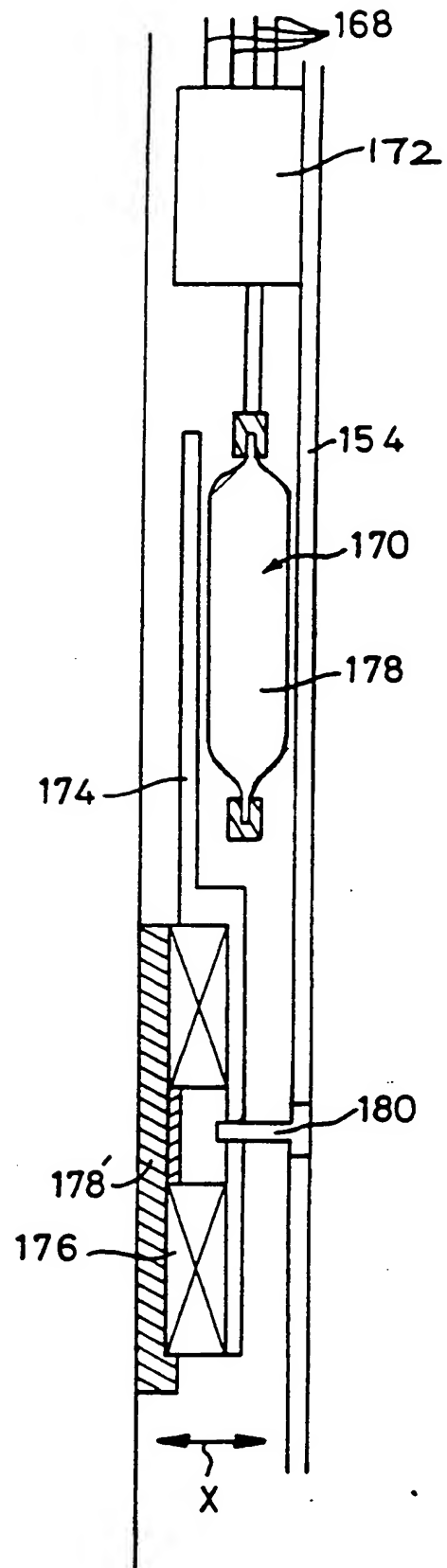
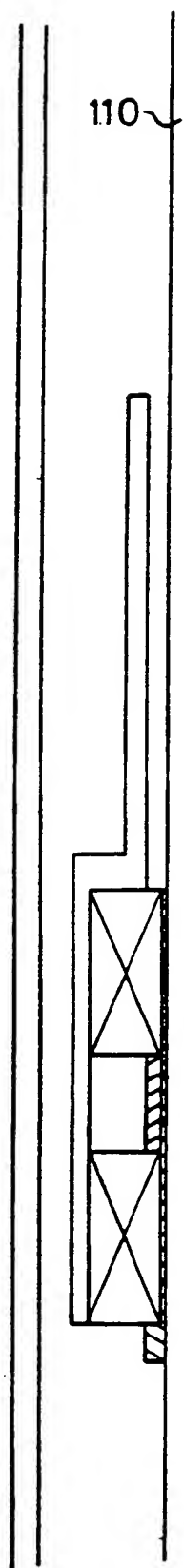
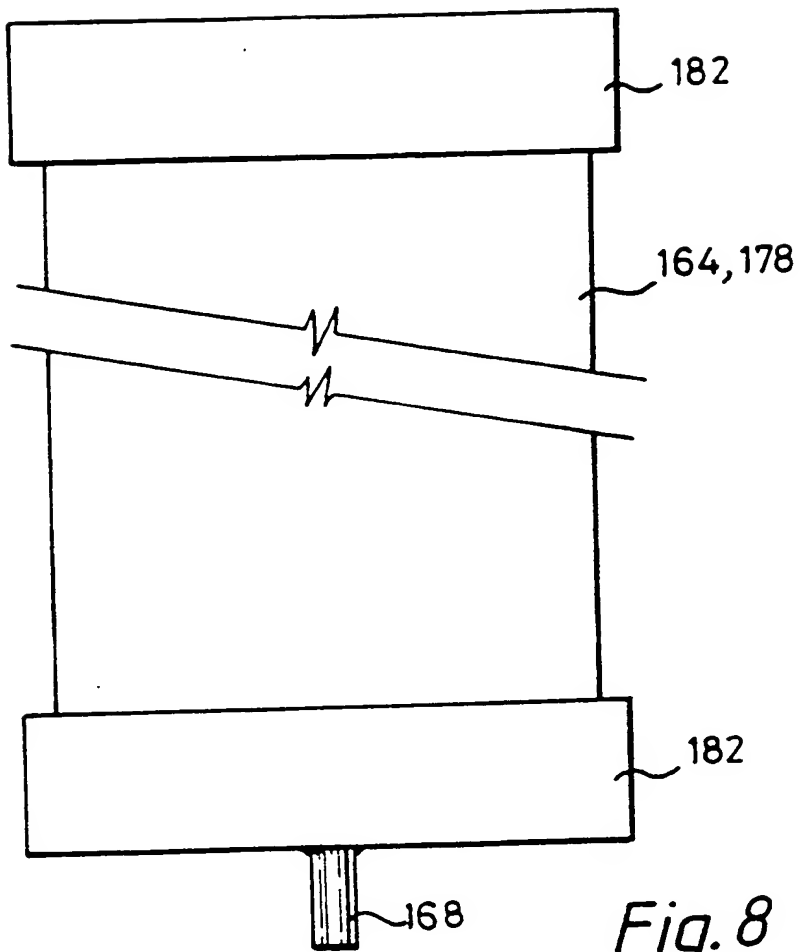
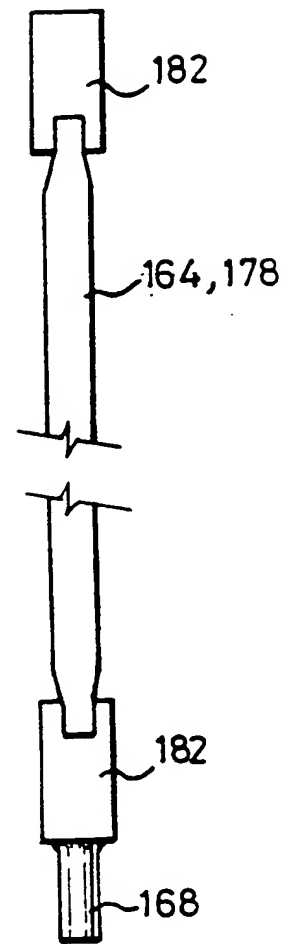


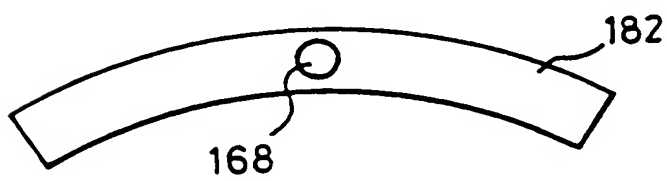
Fig. 7.



*Fig. 8*



*Fig. 9*



*Fig. 10*